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**The Role of Standards in Modern Military and Civilian
Telemetry Applications**

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The Role of Standards in Modern Military and Civilian Telemetry Applications

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Abstract

This paper describes the role of standardization in the implementation of modern telemetry communications systems. The paper examines past practices, and indicates how standardization can influence future telemetry applications. Common needs of the various military and civilian user communities are highlighted, the merits and the drawbacks of standards are discussed, and proposed criteria for deciding when and when not to standardize are suggested. The current international standardization process is described, which has emerged in response to the pressures of rapid technology advancements, increased international partnering, and decreases in both available electromagnetic spectrum and implementation resources. It is suggested that standards are more important now than they have ever been, but that the standards process must be responsive to the needs of the telemetering community and the pace of technology development. Furthermore, it is essential that all members of the community participate in the standardization process; space, aeronautical, projectile, ground vehicle and other telemetry practitioners.

Introduction

Technical standards are not new to telemetering practitioners. In the United States military community, shortly after the formation of the Range Commanders Council (RCC) in 1951, [1] the scientists and engineers who comprised the RCC's Inter Range Instrumentation Group (IRIG) began publishing the well known IRIG standards. These standards, many of which are still in use today, covered the entire gamut of the field of instrumentation, from timing to radar. Today, the IRIG standards are used worldwide by the military flight test and space community, as well as by many civil organizations. IRIG Standard 106, the telemetry standard, is a modern standard that is regularly reviewed by the members of the RCC Telemetry Group and has just recently been revised to incorporate the latest technology for bandwidth efficient modulation. [2] In the civil space world, increasing needs for international interoperability led to an urgent emphasis on space-related standardization in the late 1970s. For the past twenty years, civil space agencies – within the framework of the international Consultative Committee for Space Data Systems (CCSDS) – have been working together to develop advanced “packetized” telemetry and telecommand standards that are now in use by almost 150 missions across the world community.

The benefits of the current telemetering standards are obvious but non-trivial. Many manufacturers sell standards-compliant flight and ground instrumentation equipment, allowing project managers to purchase high quality products at competitive prices. The use of common standards facilitates exchange of data, allows the use of common data reduction facilities, and reduces the engineering design and development cost for new systems. Standards solve common problems and eliminate the need to reinvent solutions to the same problems over and over.

As with most things in life, the benefit of standards comes with a cost. Standards don't solve every problem. Design or cost considerations may preclude the use of a standard – especially if that standard pushes the envelope of current technology. There are times when political or business strategy decisions prevent the use of a standard. And arguably the greatest criticism of standards is that they impede the introduction of new techniques and technology into established practices. The benefits and detriments of standards have been argued almost since their inception. However, the rise of two phenomena in our current era require that we reexamine the concept of standardization and its role in the practice of telemetering. The first of these phenomena is the unslackening pace of technology development, the so-called "Moore's Law" effect. [3] The second phenomenon is the clear trend towards multinational partnering in the execution of complex programs. Together, these forces are changing the way the technical world views and uses standards, and the effects are beginning to be felt in the telemetry realm. Telemetering is not immune to evolution.

Telemetering Then and Now

Telemetering has been around almost since the invention of the first electrical devices. However, it wasn't until the advent of ballistic missiles that the science and practice of telemetering entered its golden age. The rocket scientists needed a way to measure what was happening on these very sophisticated and very unstable vehicles. Instrumentation engineers developed a way of collecting the output of sensors scattered about the test vehicle and sending the measurements back to the control center via a radio link. The earliest systems were in fact mechanical commutators, where a motor-driven switch sampled successive analog values sequentially, with the raw measurements being directly modulated onto a carrier for transmission to the user. As electronic switches replaced the mechanical systems, early common telemetry standards emerged. Some current-day aerospace telemetering systems still use some variation of the digital encoding methods developed in the early 1960's. Vehicle sensor measurements are digitized and represented as measurand words that represent the value of the measurement. The words are formed into frames and the serial digital bit stream sent to the telemetry transmitter where it directly modulates the transmitter carrier. This is often referred to as "PCM/FM" (pulse code modulation/frequency modulation). When the signal is received on the ground, the bit stream is reconstructed, the individual measurand words identified, and the values recorded in storage or displayed on appropriate displays.

The telemetry world is in the early stages of a revolution, being brought about by the tremendous advances in information processing technologies that are affecting almost all of life's endeavors. These advances affect the way we collect, process and transmit measurement data on vehicles, allowing us to collect more information from more sensors at much higher speeds and to deliver them directly to users. Once the data enters the ground computers, commercial networking technologies are now used to route and display the information. The next logical move is to apply these networking concepts to extend the scope of telemetering beyond the transmission of information across a point-to-point link and towards what is referred to as wireless networks. This change is already under way. There are a number of vendors who have complete ground stations that are based in large part on commercial networking architectures and software. There are products for various network type applications for use on vehicles. Some satellite programs are experimenting with Internet-derived protocols for transferring data between the spacecraft and the ground station.

The challenge to the telemetry practitioner is to make sense of all of the emerging opportunities and to take advantage of these new capabilities without bankrupting the

program budget. One way to make sense of the plethora of information is to undertake an engineering study to investigate the various capabilities, configurations, and performances. This can be a costly and time consuming undertaking. It can also result in the acquisition of a system that cannot be reused or used interchangeably between programs.

A useful way to approach this problem of technology insertion and modernization is to use the fruits of the collective labor of others who are interested in the same problems. The collective approach results in agreement on common solutions to common problems. The agreements are documented in "standards."

The Types of Standards

There are many different kinds of standards, but they can be loosely grouped into two classes - formal and de facto. De facto standards are those techniques and technologies that come into common usage not through a formal process with specific intent, but rather through the chaotic milieu of the market place or the desire to reuse something that has worked for someone else. The Space Ground Link System (SGLS) used by the US Air Force to control satellites is a de facto standard. SGLS was designed for a specific satellite program in the early 1960's and grew into the basis for the Air Force Satellite Control Network. There is no formal document called "SGLS Standard."

Formal standards are those that are developed from the outset with the specific intent of establishing a standard. There are different kinds of formal standards. "De jure" standards are imposed by government with the goal of developing new consumer-friendly capabilities. Automobile safety regulations are mostly de jure standards. There are industry standards such as IEEE (Institute for Electrical and Electronic Engineering). There are consortia standards (sometimes referred to as "technology web standards") which are published by a consortium of groups with a common interest for use by the consortium members. [4] The IRIG standards may be considered consortia standards. There are the international standards issued by the International Organization for Standardization (ISO) which stand in a category by themselves.[5] All of these standards have one thing in common; someone or some group determined a need for a standard and set out to write down the agreements reached through some formal process.

Anyone who has participated in the development of a standard can attest to the many frustrations and difficulties encountered throughout the process. Quite often, the technical challenges of the development process pale in comparison to the difficulties encountered in trying to gain acceptance and common usage of the standard. Given these difficulties, it is natural to ask the question "Why develop a standard if it is so difficult?" The question is legitimate and should be asked every time a new standard is proposed. There are a number of reasons for developing standards, and each one should be assessed before deciding to standardize or not standardize.

The Benefit of Standards

One reason for developing a standard is economics. The use of a common standard can cause the cost of an otherwise expensive new capability to be greatly reduced through commercial competition and economies of manufacturing scales. The underlying principle is that the more something is produced and sold, the less expensive it becomes. In the field of telemetry, this is illustrated by the relatively large number of standards-based commercial products available to the telemetry practitioner.

A second reason for standardizing is technical. There is a need or desire to allow the introduction of new services to provide increased capability or to achieve consistent results. Standards for telemetry signal and data structure formats allow different programs to use common telemetry services to obtain their data and process it on common ground station equipment. They also allow the exchange of data between heterogeneous organizations, thus opening new opportunities for achieving better results through partnering.

Another reason for standardization is public good. Standards can help a government achieve desired goals such as the establishment of public warning systems, aviation safety, and food and drug purity and safety. Governments may also use standards to facilitate economic development by imposing a standard when the private sector is unable to reach an agreement. A government may support the development of a standard because the standard helps the government achieve a desired goal. For example, the US DOD supported the development of a standard for a new radio frequency modulation technique because the technique helps to conserve radio spectrum, and radio spectrum conservation is a government policy in the US. This new standard will allow telemetry practitioners to obtain twice as much data in the same radio bandwidth as used previously. This is a benefit to the telemetry community, but it also helps governments meet radio spectrum management goals.

Risk reduction is another reason for adopting standards. The use of standard processes or technologies, if properly employed, can substantially reduce mission risk. This is especially true for standards that have been subject to intense peer scrutiny and test, or substantial previous use. A well-examined standard goes a long way toward eliminating surprises, especially when a mission encounters an unexpected event. For the telemetry practitioner who needs a reliable communications protocol, the use of a well-tested standard protocol reduces the risk of data loss when the radio link becomes stressed.

The reasons for establishing or adopting a standard are usually not independent. The use of a standard for achieving technical goals often leads to economic benefits as well. In the commercial world, risk reduction is measured directly in terms of profit and loss. The political decision to establish a standard often leads directly to the establishment of an industry. For the telemetry practitioner, reducing the risk of data loss can contribute to reduced test time, thereby reducing the cost of testing.

Applying these reasons to the field of telemetry, the potential benefits of standards to the telemetry practitioner can be summarized as follows: [6]

- Facilitation of data exchange
- Reduction of non-recurring costs
 - Less project-unique development
 - Shorter system test periods
 - Less training or retraining of personnel
- Reduction of recurring costs
 - More use of commercial off-the-shelf hardware
 - Fewer facilities because of use of common resources
 - Potential reduction of system redundancy
 - More automation
- Reduction of mission risk

The Drawbacks of Standards

One of the criticisms of standards is that they inhibit the introduction of new technology. This may indeed be the case, but some argue that development of the consensus necessary before the adoption and use of a standard acts as a brake on the often over-enthusiastic rush to embrace the latest technology fad. There are valid concerns on both sides of the argument. A reasoned approach must be used to decide whether or not the benefits of a new technology outweigh the benefits of the established way of doing something.

Standards can falsely appear to solve a problem for which they were not originally intended. For example, there is currently interest in using Internet protocols for telemetering applications. The underlying assumption is that the Internet's protocol suite – in particular its transmission control protocol (TCP) – would operate over a noisy radio path with significant delays in the same manner that it does over a wire. Unfortunately, TCP has fundamental design features that make it inherently difficult to use in radio environments with moderate amounts of noise. A modified TCP can be used over such connections, but it requires knowledge and careful analysis to determine what is needed to make it work. The existence of a standard, in and of itself, is therefore not a sufficient reason for using it.

A poorly designed standard can make a problem worse than the problem which the standard was intended to solve. For example, a standard may be intended to promote interoperability between many systems and users. However, in order to make the standard as flexible as possible so that many users will adopt it, the standard is designed with many "options" that a user can select. The result is that every user has a unique configuration with which no other user can interoperate. The lesson is twofold; standards must be designed carefully, and users must understand a standard before adopting it.

Standards can create inefficiencies and increase costs. For example, the US Department of Defense (DOD) routinely imposed standards on acquisition contracts that forced manufacturers to use out-dated or unique manufacturing techniques. This increased the cost of the product. It has taken many years to eliminate this practice; the DOD now specifies "best commercial practice" whenever possible in a contract. For the telemetry engineer, using an old standard that is not commonly used elsewhere and is based on obsolete technology could increase costs by forcing the need for system modifications, technical or procedural compromises, or costly maintenance of obsolete equipment or software.

There are times when a standard simply does not exist for a particular undertaking. In these instances, there is simply no choice but to develop the necessary capability. If there is a possibility of the new capability being useful to many users, consideration may be given to adopting the specification as a standard for the new capability.

In sum, there are valid reasons for not using standards, just as there are valid reasons for using them. However, the benefits of standards almost always outweigh the drawbacks.

Standards and the New Telemetry Concepts

Not too long ago, telemetry practitioners did not have too many choices when it came to deciding what standards to use, if any. The choice is not as simple today and it has the potential to become less so in the future. The developments in network technologies

are beginning to be felt in the telemetry world. Packetized data communications has long been used in networks, and the surge in Internet capabilities has led to the emergence of extremely large and efficient data communications infrastructures. Young engineers come to the telemetry labs thinking about data communications in ways that are very different than just ten years ago. This has led to experimentation with new ways of doing telemetry.

There are new developments in the telemetry radio as well. The most significant recent development is probably the RCC's adoption of a standard for efficient modulation of the radio waveform. This standard, based on Feher's Quadrature Phase Shift Keyed (QPSK) modulation technique, led directly to the marketing of QPSK-compatible products by telemetry equipment vendors. Telemetry radios will continue to evolve as more efficient modulation techniques and software-based radios emerge from the laboratories and are adopted as standards.

As these new concepts and capabilities become available, the telemetry practitioner is faced with an increasingly complex set of choices. Furthermore, the new capabilities may not fully address the needs or concerns of the practitioner. A partial solution to this problem is for the practitioner to become involved with the processes that lead to the adoption of standards. At first glance these processes appear to be as complex as the new technologies, but with respect to telemetry, they are well defined and accessible to everyone. The incentive for developing these standards is that the telemetry community gains the advantages of standards as described above.

The Modern Standardization Process

The Consultative Committee for Space Data Systems (CCSDS) is an international organization that prepares standards in the form of formal Recommendations. There are several CCSDS Recommendations¹ that provide for the transmission of packetized data [7, 8]. Along with these concepts comes the need for data routing, data compression, security, reliable transport, and network management. Standards for these services, as they apply to telemetry, are either in existence, in development or under consideration.

Within the past decade, the role of international standards and the associated standards bodies has increased greatly. International standards are beginning to appear within the telemetry realm. For example, in the US military range community the RCC is in the final stages of adopting the CCSDS packetized telemetry standard that is in widespread use across the civil space community.

Figure 1 illustrates the process of developing a standard within CCSDS. The process often begins when a member agency, for example, NASA, indicates a need for a new or revised standard. The proposal is submitted to the appropriate CCSDS technical panel or the Technical Steering Group. If the proposal is accepted, it is assigned to an appropriate subpanel which undertakes the development of the document. The document undergoes substantial iteration and numerous reviews before it is submitted to the Management Council as a finished document.

¹ CCSDS Recommendations are submitted to ISO for adoption as standards, but the Recommendations themselves are often referred to as "CCSDS standards."

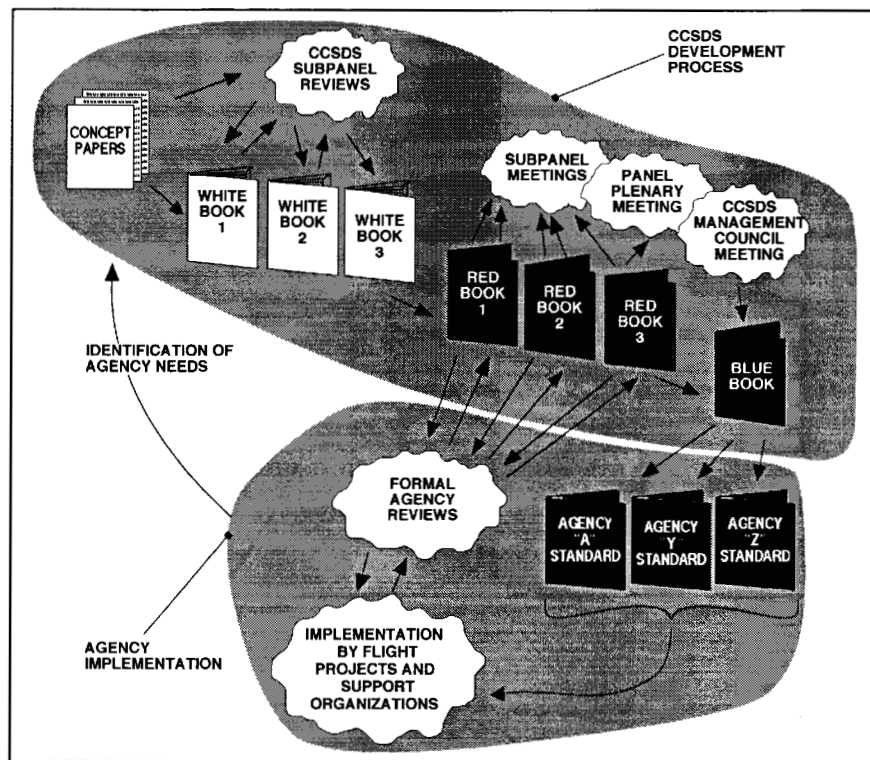


Figure 1. CCSDS Standards Process [9]

The final document, referred to as a "blue book" because of the color of the cover, becomes a published "recommendation" of the organization. The document is then available free of charge for adoption by any standards body, program office or individual who cares to use it. In the final stages of their development, the CCSDS Recommendations are usually processed through to full International Standards via ISO Technical Committee 20, (TC 20 Aircraft and space vehicles), Subcommittee 13 (SC 13 Space data and information transfer systems). Key to this process is the involvement of experts from the agencies and organizations that will use the document. In actual practice, the people who develop the document are often members of user agencies or are support contractors to the agencies. These same people may be responsible for implementing the standard when it is complete.

There are several motivations for an agency, organization or individual to participate in the standards process. The national space agencies that formed the CCSDS were motivated by economics and the desire to share information. An organization may be motivated to participate in order to ensure that a specific technical need is addressed. A commercial company may participate because the company has a vested interest in products that would implement the standards produced by the process. Individuals often participate because of professional interest or the opportunity to help further their chosen profession. Regardless of the motivation, anyone who is interested in participating in the telemetry standards process may do so. Even if a person's employer does not have the funds to pay for travel or labor costs, one can at least participate by requesting to be placed on the reviewers list. The only caveat is that the request to participate implies an obligation to contribute, even if the contributions are review comments.

The growth of international standards is viewed by some as a threat to existing national, industrial, and other specialized standards organizations. Some individuals within these lower tier organizations view the international organizations as preemptive, rendering the lower tier organizations superfluous and therefore redundant. Such is not the case.

The lower tier organizations play a more important role than was previously the case. They provide the technical expertise and resources needed to develop, test and maintain standards. Equally important, the lower tier organizations interpret the base standards, adapting them to the specific needs of the interest groups they represent. This interpretation is called "profiling," and is an important and major feature of modern communications standards.

Conclusions

We stated earlier that the next revolution in telemetry will be the adoption of wireless real time networking concepts, and that this change is already in its formative stages. We argue that there are substantial benefits to be gained by developing or adopting standards for the new telemetry concepts. In our judgement, the detriments of standards are greatly outweighed by their benefits. In order for the new standards to be useful to the greatest number of telemetry practitioners, they must be targeted towards the broadest possible market in order to attract commercial investment in their realization. The civil and military telemetering environments – both space mission and test ranges – share many more common problems and solution spaces than they have differences. We recommend therefore that telemetry practitioners from diverse traditional backgrounds should become involved and united in the standardization process in order to ensure that the new technologies can be tailored to meet the needs of those who measure from afar.

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